Sensor Cleanliness and Sterility Issues

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JPL Workshop on Planetary Protection

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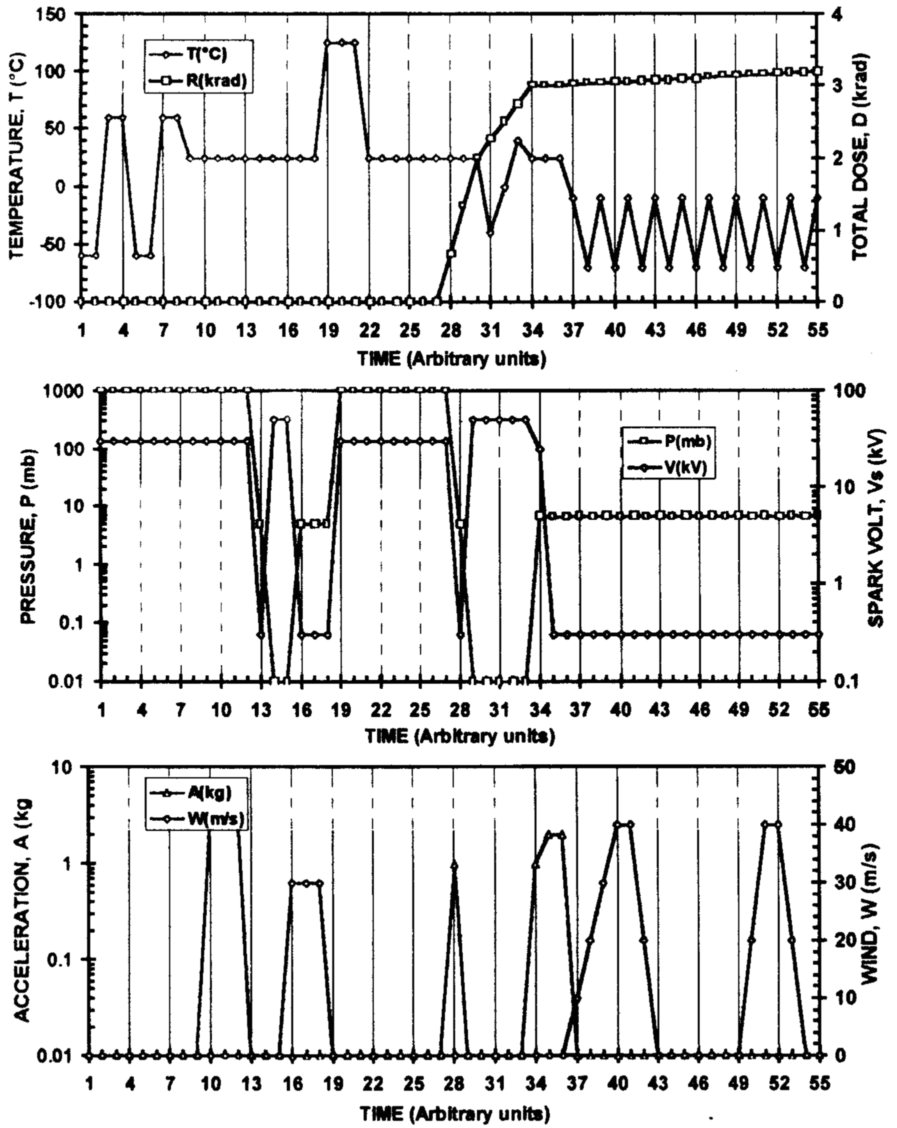
INTRODUCTION

- **OBJECTIVE:** to discuss the effects of cleaning and sterilization procedures on sensor performance.
- **OUTLINE:**
  - Sensor environment
  - Candidate cleaning and sterilization procedures
  - Sensor examples:
    - Radiation Monitor
    - Electronic Nose
    - Mars Oxidation Experiment
  - Effects of cleaning and sterilization on sensors
  - Conclusion

Sensor Cleanliness and Sterility

Life-Cycle of a Mars Bound Sensor



TIME, t, INCREMENT	ACTIVITY	TIME, t, INCREMENT	ACTIVITY
1	Temperature Cycle Test	28	Launch
4	Temperature Cycle Test	31	Cruse
7	Temperature Cycle Test	34	Mars Landing
10	Acceleration Test	37	Mars Operation
13	Outgassing Test	40	Mars Operation
16	Wind Test	43	Mars Operation
19	Burn In Test	46	Mars Operation
22	Integration	49	Mars Operation
25	Delivery	52	Mars Operation

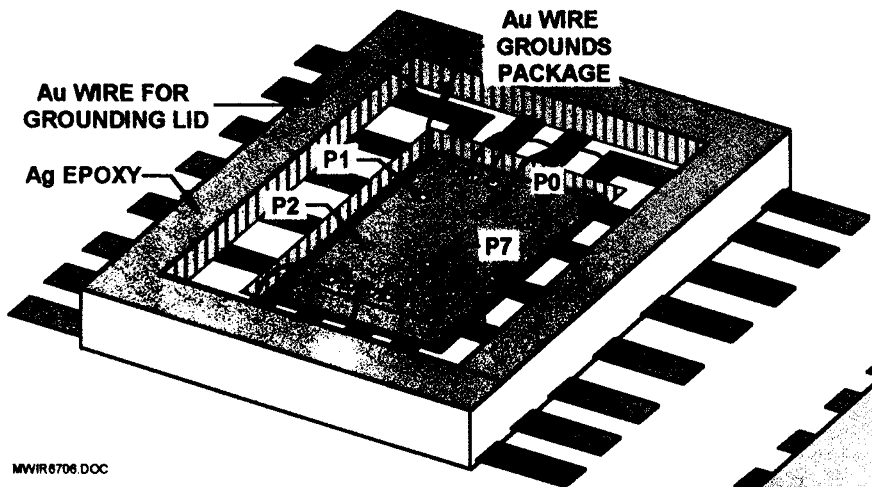
- **Many factors are considered in sensor design.**
- **However, planetary protection usually has a low priority.**
- **Planetary protection needs to be considered throughout sensor design, fabrication, launch and operation.**

Candidate Cleaning and Sterility Procedures

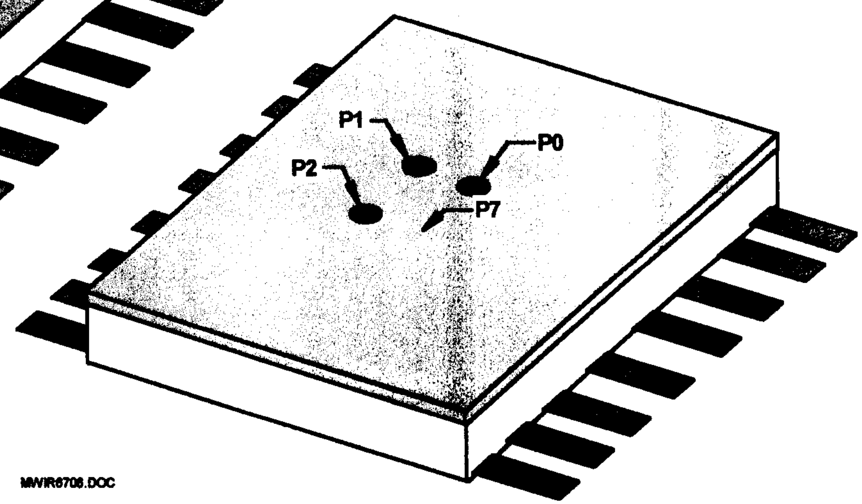
PROCEDURE	COMMENTS
Heat	105 to 135°C for several hrs
Alcohol Wipe	Removes bacteria but not organics.
Hydrogen Peroxide Plasma	
O_2 Plasma Cleaning	Pressure 25 to 100 mb
Chlorine Dioxide	Gas exposure, surface abrasion
Paraformaldehyde	Gas exposure
Ethylene Oxide	Gas exposure
Wet Steam	Autoclaving
Cleaning Baths	Water based Semi aqueous Solvents (TCE equivalent)
Freon Wash	
Ultra Violet	
Gamma Irradiation	

Cleaning Destroyed Radiation Monitor

Part without lid showing wire bonds



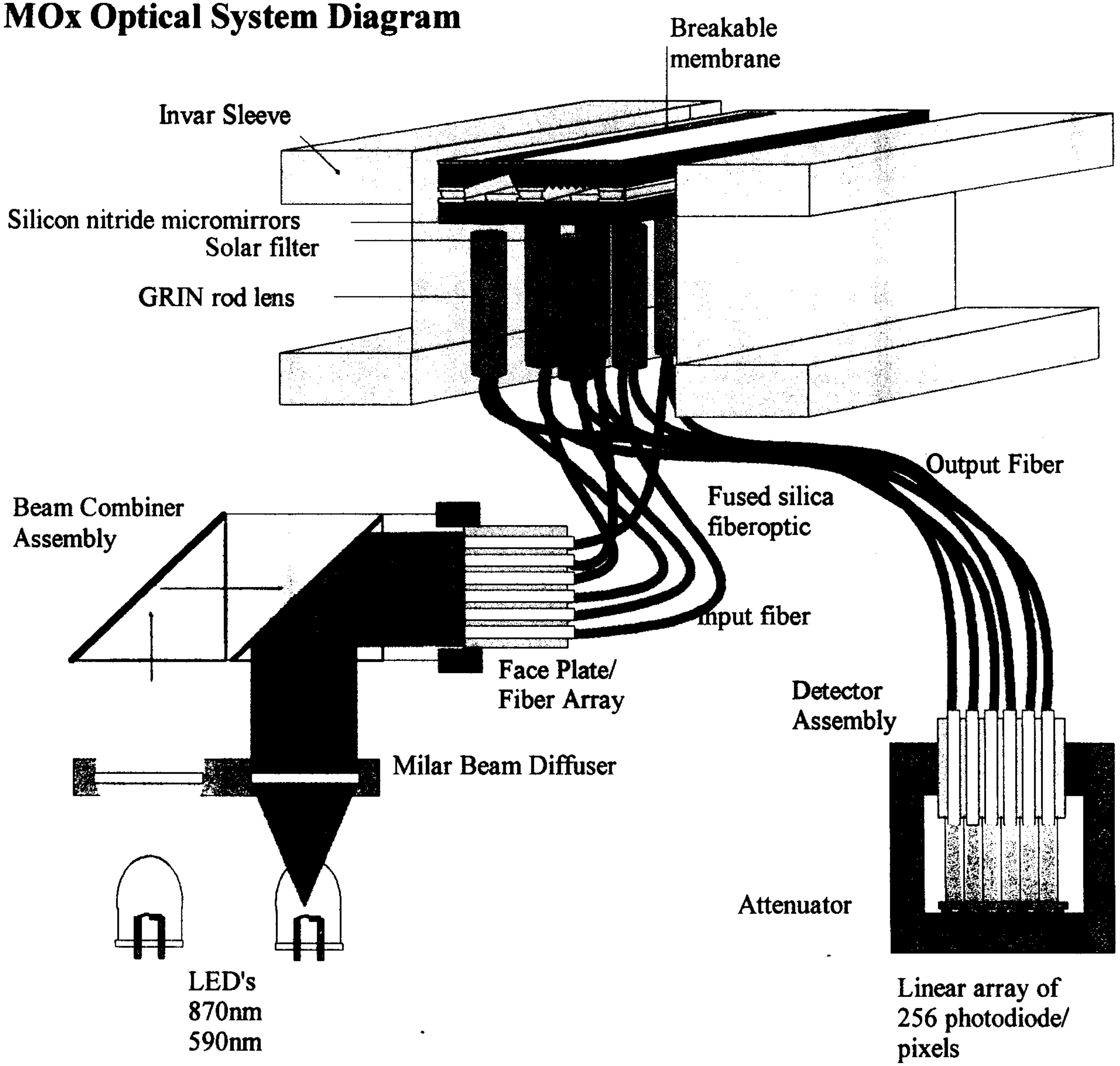
Packaged part with hole in lid at P1



After radiation monitor was soldered onto a printed circuit board, the board was cleaned using an ultrasonic cleaning bath. This procedure broke the wire bonds.

MARS OXIDATION EXPERIMENT

MOx Optical System Diagram



MARS OXIDATION EXPERIMENT

COATING	PURPOSE
Magnesium	Very high reactivity to oxidants
Aluminum	High reactivity to oxidants; oxide is allowing intrafilm reaction
Titanium	Moderately high reactivity to oxidants; well studied in the laboratory
Vanadium	Moderate-to-high reactivity to oxidants; rich and variable oxide chemistry
Silver	Low reactivity, but extremely reactive to ozone, oxygen radicals, sulfur compounds
Palladium	Low reactivity but sensitive to hydrogen, sulfides, unsaturated hydrocarbons
Thin gold	Frost indicator; reactive to sulfur compounds; organic adsorption indicator (+2.0 nm Cr) Constant-reflectivity reference (+40.0 nm Cr)
Thick gold	Constant-reflectivity reference (+40.0 nm Cr)
Hydrocarbon-A	Analog of highly refractory kerogens(organics) found in meteoritic infall
Hydrocarbon-B	Analog of moderately refractory kerogens (organics) found in meteoritic infall
C60	Carbonaceous material, sensitive to combination of UV and oxidants
L-cysteine	To detect enantiomeric preference in reactions with, or catalyzed by, martian soil
D-cysteine	To detect enantiomeric preference in reactions with, or catalyzed by, martian soil
Thymol blue	pH indicator dye: pK1 = 2.0, pK2 = 8.8
Bromphenol blue	pH indicator dye: pK = 4.0
Bromcresol purple	pH indicator dye: pK = 6.3
Bromcresol purple	Fluoresces only at neutral or basic pH
Chlorophyllin	Ozone detection via ozonolysis of carbon-carbon double bonds
Iron porphyrin	May bind CO with color change
Copper Pc	Well-characterized sensor material for oxidants(Pc = phthalocyanine)
Lead sulfide	Reacts with hydrogen peroxide with large color change
Uncoated	Dust accumulation, surface film buildup, and ambient light level reference

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Sensor Cleanliness and Sterility

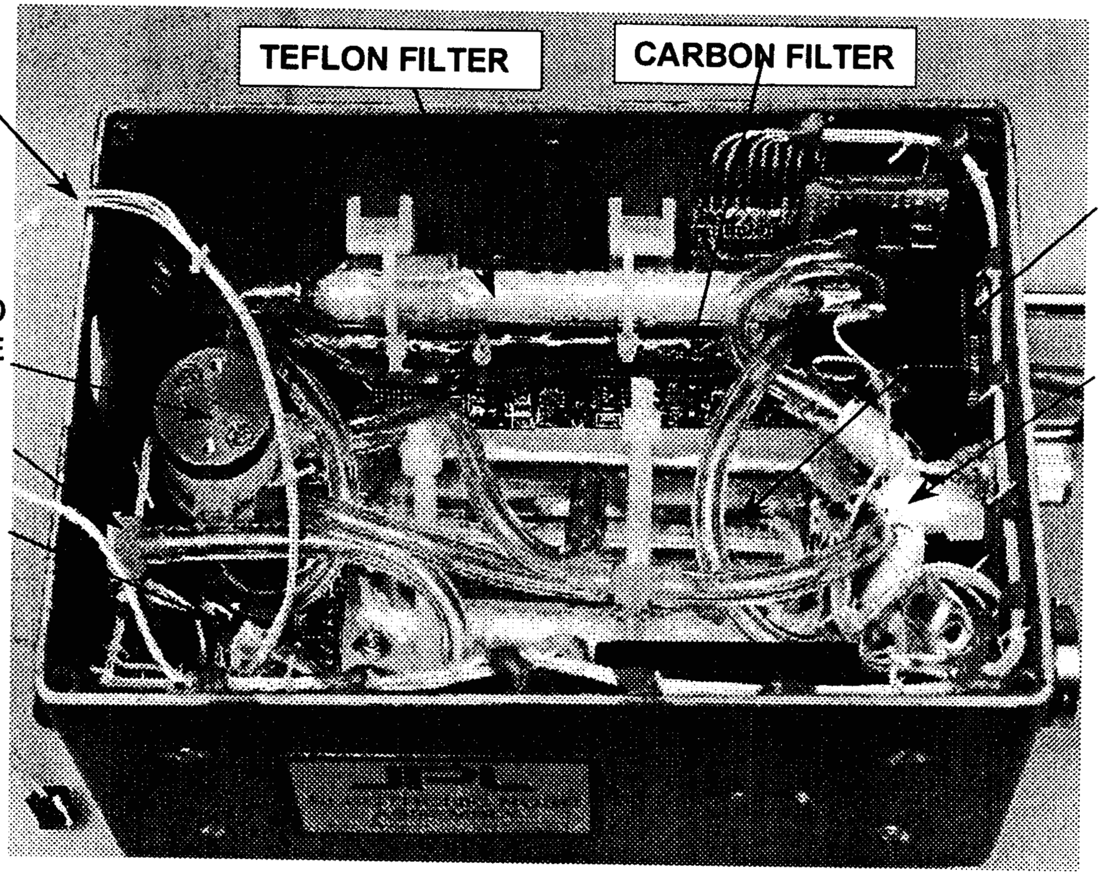
SHUTTLE STS95 FLIGHT EXPERIMENT

RS232 SERIAL CABLE TO HP 200 LX PALM TOP INCLUDED IN FLIGHT BOX

SOLENOID VALVE

AIR OUT

AIR PUMP 250 cc/min



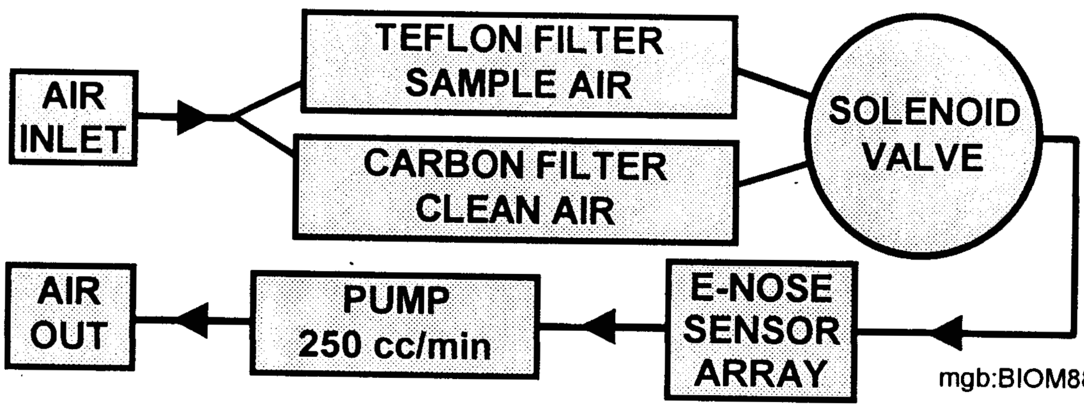
SENSOR ARRAY W/ 16 POLYMER SENSOR PAIRS IN GLASS CHAMBER

AIR INLET

POWER (nominal) = 2 W

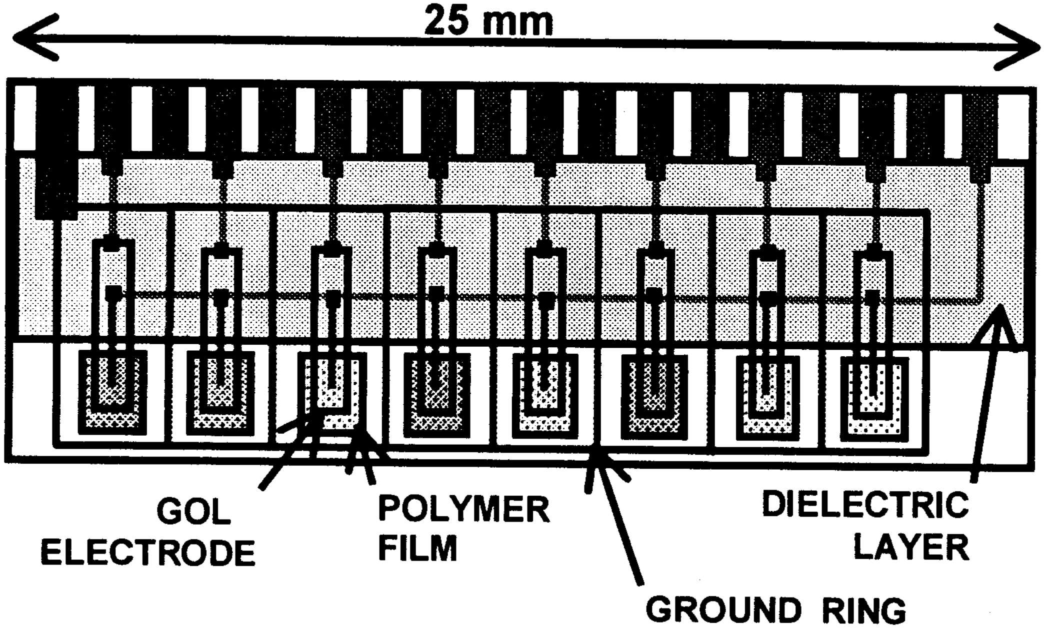
POWER (peak) = 3W

POWER SUPPLIED BY SHUTTLE



Sensor Cleanliness and Sterility

E-NOSE SENSOR CHIP



Chip consists of double-level Au electrodes screen printed on an Alumina substrate. Substrate is 10 mm x 25 mm with 2.5 mm between polymers which are deposited in a solvent that evaporates to deposit the sensing film. RuO_2 heaters are fabricated on the backside and keep the substrate at 28°C.

TEN TARGET GASSES

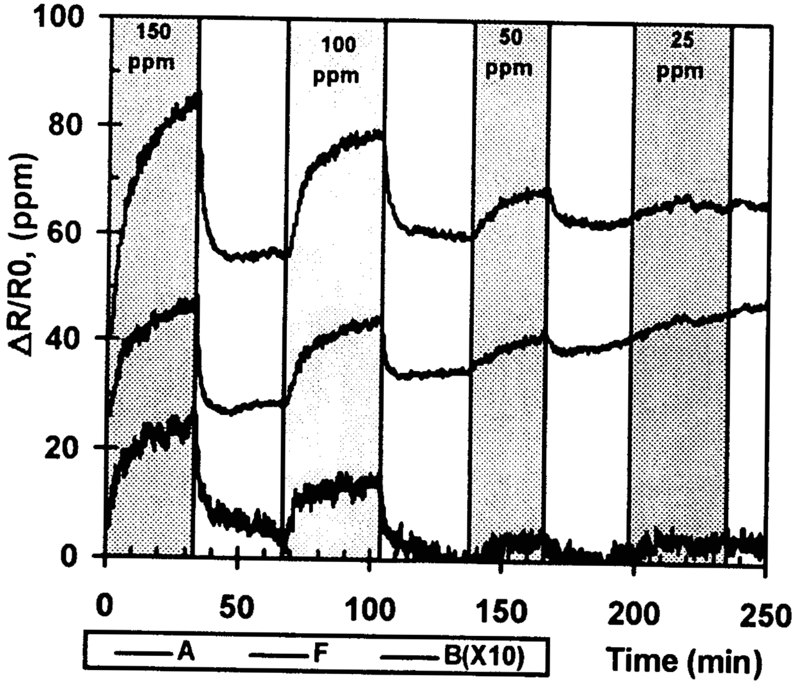
Compound	Detection Limit (ppm)
Methanol	5
Ethanol	25
2-propanol	50
Methane	3000
Ammonia	10
Benzene	10
Formaldehyde	10
Freon 113	25
Indole	0.03
Toluene	15

Detection limits governed by:
- Choice of polymers
- Baseline drift
- Gas flow over sensors
- Temperature (<50°C)

E-NOSE OPERATION

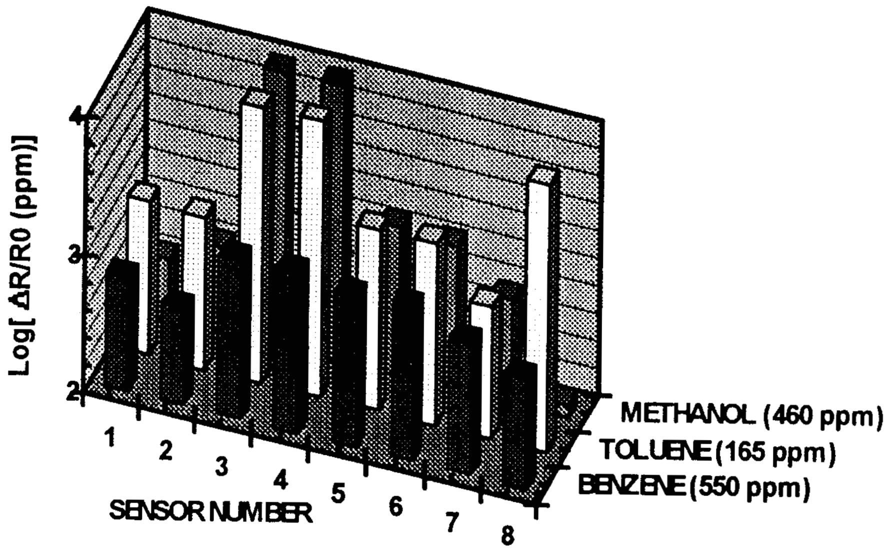
E-Nose consists of an array of carbon impregnated, insulating polymer sensors. Gasses cause polymers to swell which changes the polymer resistance. Resistance of polymer recovers when residual gas removed.

Chart shows the response of three polymers to a methanol exposure with a time response of the order of 10 min.



A = poly(4-vinylphenol)
F = poly N-vinylpyrrolidone
B = polystyrene allyl-alcohol

Chart shows four sensor pairs exposed to three gasses. The response of the first three pairs track. The lack of tracking of polymers 7,8 eliminates them as candidates.



Toluene and benzene are very similar chemically; but, they are easily differentiated in the responses of polymers 3,4 and 5,6.

Sensor array is "trained" and the response entered into a data base. Currently, the change in response is measured 20 minutes after the onset of the exposure.

End-of-Fabrication Cleaning Procedures

- Solder temperatures: 185 to 210°C for a few seconds provide a degree of sterility.
- Solder Flux Removal: Organic degreasers in an ultrasonic bath probably degrade the sterility.
- Surface cleaning: Organic degreaser, acetone, and alcohol rinse regain some sterility.
- Overcoat: "Seal" in surface contamination but may harbor other kinds of contaminants.
- Oxide removal: Plasma etching removes Al2O3 on Al

End-of-Fabrication Cleaning should begin the start of the planetary protection procedures

Cleanliness and Sterility Material Issues

REGION	MECHANICAL ABRASION	GAS and PENETRATING RADIATION
Exposed Surfaces	YES	YES
Re-Entrant Surfaces	NO	YES
Porous Materials	NO	YES

•Sealed components: One way to "eliminate contamination is to seal it in using Hermetic seals or overcoats.

•Some areas are available during assembly but unavailable after assembly.

Sensor Parameters affected by Cleaning Procedures

SENSOR PARAMETER	EXAMPLES
High Voltage	Contamination increases leakage in plasma detectors
High Impedance	Contaminates increase leakage in electrometer
Delicate Feature	Exposed wire bonds in particle detectors Wire grids in plasma detector
Temperature Limitations	E-Nose polymers limited to < 60°C
Sensitive Surfaces	MOx surfaces require a hermetic environment Lens coatings sensitive to plasmas
Plasma Sensitivities	Board coatings removed by plasmas Oxide charge induced by plasmas
Board Coatings (Glob Top, Paralyne)	Materials are porous and harbor contaminants
Gamma Radiation Limitation	Oxide charging affects sensor (CCD's, APS) operation

CONCLUSIONS

- Cleaning sensors can require a number of procedures especially multi-sensors.
- Procedures used to clean sensors needs to be designed into the assembly sequence.
- The operation of the sensors on a lander/robot needs to be coordinated to mitigated cross contamination.
- Sensors need to be designed with PP in mind. But the sensor community knows very little about PP procedures. Hence, sensors are poorly designed from a PP standpoint. Thus, the sensor community needs guidelines to help in choice of materials and mechanical designs that aid PP.